

# **Space Human Factors Engineering Project Plan**

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**Habitability and Human Factors**

**Habitability and Environmental Factors Office**

**November 2001**



National Aeronautics and  
Space Administration  
**Lyndon B. Johnson Space Center**  
Houston, TX 77058

# **Space Human Factors Engineering**

## **Project Plan**

**Habitability and Human Factors, Habitability and Environmental Factors Office  
Space and Life Sciences Directorate  
Lyndon B. Johnson Space Center, National Aeronautics and Space Administration  
Houston, Texas**

**November, 2001**

### **APPROVALS**

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ACRONYMS

AHST	Advanced Human Support Technology
BRD	Bioastronautics Research Division
ISS	International Space Station
NRA	NASA Research Announcement
NSBRI	National Space Biomedical Research Institute
OBPR	Office of Biological and Physical Research
SHFE	Space Human Factors Engineering
STWG	Science and Technology Working Group

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## **1.0 INTRODUCTION**

As the frequency, complexity, and duration of human forays into space increase, human factors research and development will grow more and more important to mission success. Isolation, confinement, and boredom, coupled with high performance demands, make human stays in space stressful and risky. And as missions grow longer, demands on crews for technical assistance and troubleshooting will grow. Such conditions require that humans and machines work together as safely, efficiently and productively as possible. Reducing stress will reduce risk, and reducing risk will improve safety. Efficiency and productivity inevitably will benefit from this approach to mission planning.

Space missions are incorporating an ever-broadening array of equipment requiring crew attention, complicating information flow and decision-making. (Crew displays and controls alone have increased by two orders of magnitude in number since the first U.S. space flight.) As the complexity of human-machine interface and crew interaction increases, so does the risk of human error. NASA's Space Human Factors Engineering (SHFE) Project focuses on reducing human error and the potential disasters that can result.

Human-rated space environments must be as "user-friendly" as possible, and crew members must be fully aware of system functions, capabilities, and limits. Crew members also must be fully aware of their own and their colleagues' functions, limits, and capabilities. And understanding how the space environment affects group dynamics is equally important. Human factors research and development must provide the tools to ensure that crews and spacecraft systems are as compatible and complementary as possible, optimize the mix of human and automated operations, reconcile potentially conflicting requirements for living and working, balance comfort with efficiency and productivity, and avoid potentially deadly overconfidence in "the system."

The purpose of the SHFE Project is to create and maintain a safe and productive environment for humans in space. With missions absorbing new technologies at an ever-increasing rate, it is imperative that planners can ensure these advances will enhance crew performance without increasing stress or risk. This SHFE Project Plan provides a framework for the SHFE Project, identifying concerns needing human factors attention and highlighting the value of human factors throughout the Agency. It includes a general discussion of the SHFE Project, a description of objectives that outline the overall project strategy, and a management approach. This document supercedes the Space Human Factors Program Plan (December, 1995). SHFE Project implementation plans, which are produced annually, complement this project plan by specifying details of how objectives will be accomplished each year.

The SHFE Project is an interdisciplinary effort covering all aspects and facets of the general discipline of human factors engineering and sharing selected aspects of the behavior and performance discipline of the Biomedical Research and Countermeasures Program. The SHFE Project encompasses a broad range of activities from basic research

and development of state-of-the-art tools for measuring human performance to applying those tools to solve operational human/system interface issues in human space flight programs. Additionally, developing new technologies and conceptual designs for flight crew accommodations needed for human missions beyond Low Earth Orbit, is also considered within the purview of the Project's responsibilities. Figure 1 shows how the SHFE Project fits within the Office of Biological and Physical Research (OBPR) as an element of the Advanced Human Support Technology (AHST) Program.

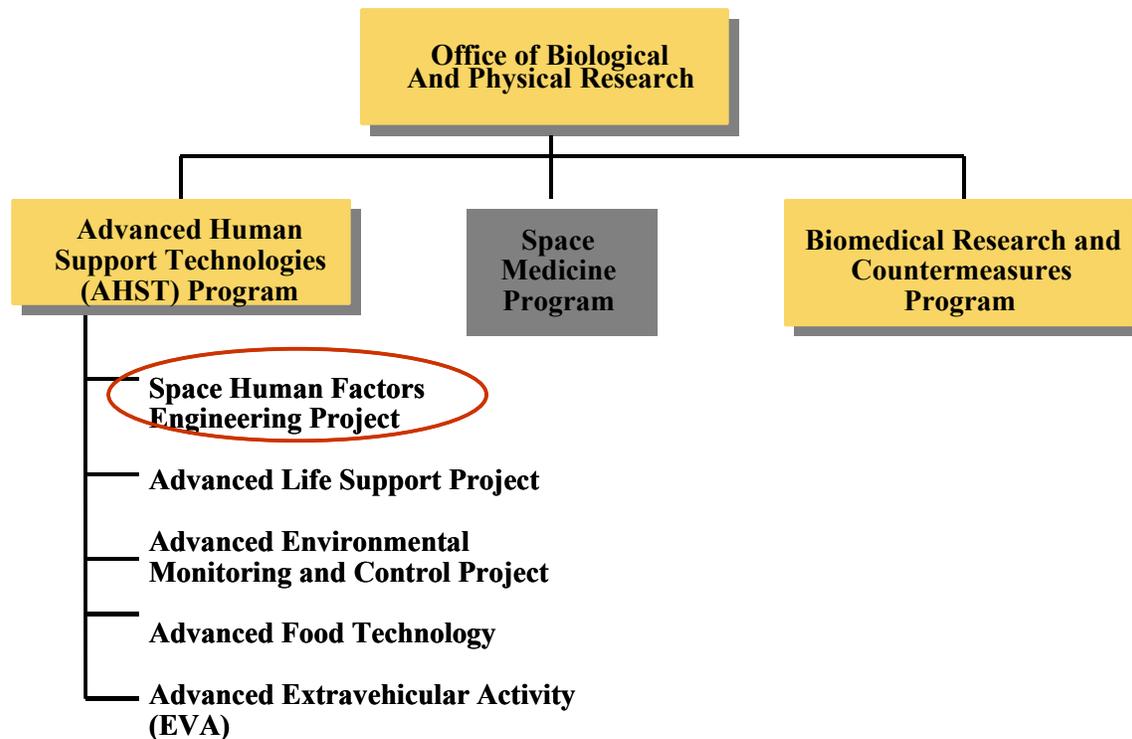


Figure 1. Organizational chart showing SHFE Project as element of AHST under Office of Biological and Physical Research.

There are two major activity paths contained within the SHFE Project:

- The traditional NASA Research Announcement (NRA) process allows investigators to submit proposals annually for basic human factors research. The proposals are peer reviewed, selected by NASA Headquarters, and usually result in 3-year grants for successful bidders. SHFE Project management personnel participate in the process by defining human factors content in the annual NRA call and reviewing proposals for relevancy to operational space flight and critical research needs.

- Technology development projects facilitate mid-level technology advancements and address needed critical research. The process for selecting projects is defined in the Management section of this plan.

In addition, the National Space Biomedical Research Institute’s (NSBRI’s) core research program is expected to become more relevant to applied SHFE as the Institute grows and matures.

These activity paths are the available mechanisms for accomplishing SHFE project goals, and they are depicted graphically in Figure 2.

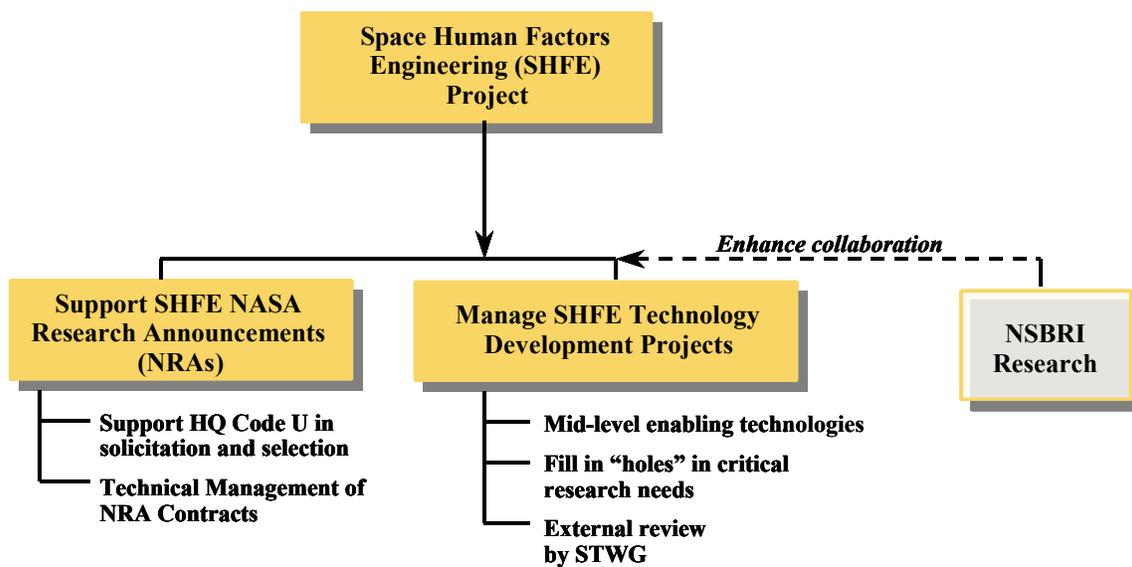


Figure 2. SHFE Project activity paths.

Various segments of essential SHFE expertise are distributed across different NASA centers, at other government agencies and laboratories, at a number of academic institutions, and within the private sector. The SHFE Project is intended to provide focus, integration, and oversight to the widely diverse and geographically dispersed team. This plan only addresses the research and development needs of the SHFE Project, and does not impose another layer of management or protocol on any existing activity that responds to current programmatic needs in the Agency.

## **2.0 PROJECT GOALS/OBJECTIVES**

The SHFE Project goals are to:

- Expand knowledge of human psychological and physical capabilities and limitations in space by conducting basic and applied research, tests, and evaluations. Research will address the psychosocial, cross-cultural, physiological, perceptual, cognitive, biomechanical, and motor-skill effects of various space mission environments. Research will focus on advancing scientific knowledge and meeting customer needs. Mission tasks to be performed by humans will be identified, and human factors research and engineering will be applied to improve performance, allocate functions, and increase safety and productivity. Quantitative models of human-system interactions and capabilities will be developed for use in planning both flight and ground-based activities.
- Develop cost-effective technologies that support integrating the human and system elements of space flight. Human factors researchers will identify, design, evaluate, and implement technologies with high payoffs in human productivity and safety.
- Provide mission planners with human factors research results and technology developments to increase mission success and crew safety. The Program will expand communication and cooperation among experts in human factors research and in space flight operations to ensure that human factors principles and methodologies will be integrated into space flight programs. Input from human factors specialists ultimately will become an integral part of the development process, initiated as early as possible in the mission analysis phase.
- Make NASA technology available to the private sector for Earth applications. NASA also will use new technologies developed by private industry where appropriate. NASA and private industry will cut costs by forming partnerships to develop products of mutual benefit.

The overall objective of the SHFE Project is to develop enabling technologies required for successful human habitation and performance on very long duration, exploration-class missions. Research tasks required to accomplish this are defined by the Space Human Factors: Critical Research and Technology Definition document (October, 1996, [http://peer1.nasaprs.com/peer\\_review/prog/prog.html](http://peer1.nasaprs.com/peer_review/prog/prog.html)) and the Critical Path Roadmap (CPR) for human exploration and development of space (<http://criticalpath.jsc.nasa.gov/>). Section 5 of the National Research Council Committee on Advanced Technology for Human Support in Space, Aeronautics and Space Engineering Board report is also a useful reference.

The SHFE Project's objectives include advancing the state-of-the-art and developing standards for such items as human-machine interfaces, habitation systems and interior layout, information management, human performance modeling, training and

performance assessment technologies, and general human factors applied research and analysis. For example, as human space flight missions extend in duration and distance from Earth, advanced systems will be required which allow the crew to be self-sufficient with respect to information and supplies currently provided by ground control and support teams. Additionally, far greater onboard responsibility and authority for planning mission tasks and assessing crew readiness will be required.

### **3.0 CUSTOMER DEFINITION AND ADVOCACY**

The primary customer for the SHFE Project is the Bioastronautics Research Division (BRD) of the OBPR at NASA Headquarters. Customer advocacy is ensured by BRD's roles in the NRA solicitation and selection process and in budget planning and funding allocation. Customer insight into the project is accomplished through regular status reporting up through the AHST Program and OBPR.

### **4.0 PROJECT AUTHORITY**

Authority for the SHFE Project flows through the Program Commitment Agreement for the AHST Program, into the AHST Program Plan, and subsequently into this SHFE Project Plan. Lead Center responsibility for the AHST Program is delegated to JSC, where the management for both the AHST Program and the SHFE Project resides.

### **5.0 MANAGEMENT**

#### 5.1 Organization

The SHFE Project is managed by the SHFE Project Manager who reports to JSC Center Management and to the AHST Program Manager. The SHFE Project Manager directs and controls activities necessary to achieve Project goals and ensure customer satisfaction. The SHFE Project Manager is assisted by a Deputy Project Manager and a Discipline Coordinating Scientist. In order to enhance participation on the Project by Ames Research Center, the project's core management team also includes a SHFE Project Deputy Manager for Ames Activities. Intramural and extramural activities each have a designated Principal Investigator, who oversees day-to-day activities and reports to the SHFE Project Manager. An SHFE Science and Technology Working Group provides guidance and recommendations to the SHFE Project Manager.

#### 5.2 Responsibilities

##### 5.2.1 SHFE Project Manager

The overall management of the SHFE Project is the responsibility of the SHFE Project Manager. The specific responsibilities of the SHFE Project Manager are:

- Develop, update, and maintain the SHFE Project Plan, in cooperation with functional managers in participating and sponsoring organizations.
- Direct and control activities necessary to accomplish the goals and objectives of the Project and to ensure customer satisfaction.
- Perform technical management of Project work – recommend priorities and distribution of resources.
- Coordinate SHFE activities with those of other AHST projects.
- Provide systematic status reporting to the AHST Program Manager.
- Coordinate SHFE activities with those of related programs in other government agencies, such as the Defense Advanced Research Projects Agency
- Appoint the Deputy Project Manager and the Discipline Coordinating Scientist, and direct and coordinate their efforts.
- Provide for Technical Monitoring of SHFE NASA Research Announcement awarded activities.
- Represent the SHFE Project at appropriate conferences, meetings, etc.
- Serve as member of the AHST Configuration Control Board.
- Provide for Education and Outreach Activities.
- Achieve Project milestones.

### 5.2.2 Deputy Project Manager

The SHFE Deputy Project Manager assists the Project Manager in executing the above responsibilities.

### 5.2.3 Deputy Project Manager for Ames Activities (DPM-ARC)

The SHFE Deputy Project Manager for Ames Activities represents Ames Research Center (ARC) human factors researchers to the SHFE Project, and the SHFE Project to the human factors researchers at ARC. The DPM-ARC assists the Project Manager in executing the above responsibilities.

### 5.2.4 Discipline Coordinating Scientist (DCS)

The DCS represents the SHFE Project in appropriate NRA SHFE activities, including recommending NRA content to NASA Headquarters' BRD and being present at the SHFE NRA selection panel discussions. Other responsibilities include:

- Serve as an interface with the extramural human factors engineering community, including industry, academia, and other government agencies.
- Identify and facilitate opportunities for collaboration.
- Identify new tools and technological advances that can support SHFE Project goals.
- Facilitate operation of the Science and Technology Working Group.
- Assist the SHFE Project Manager in developing and implementing the goals and objectives of the SHFE Project.
- Participate in evaluating NRA and technology development project proposals for feasibility and relevance.

### 5.2.5 SHFE Science and Technology Working Group (STWG)

The function of the SHFE STWG is to provide guidance and recommendations to the SHFE Project. Examples of STWG activities are as follows:

- Assess and make recommendations on top-level strategy and direction of the SHFE Project and on how to best ensure that SHFE practices and principles are to be incorporated into NASA operations.
- Assess and make recommendations for SHFE Project balance with respect to distribution of funded tasks: e.g., across research and technology development;

- ground and flight tasks; near and far-term activities; research and development vs. integrated systems and operational testing; and NRA grants vs. project level activities.
- Conduct reviews and scientific/technical evaluation of specific projects or tasks within the SHFE Project.
  - Review and offer input to SHFE Project Documents, including Project Plans, Roadmaps, SHFE Requirements Document, and SHFE Technology/Research Assessment Matrix.
  - Assist the Project in developing options for implementation, e.g., future directions, projects, and alternative approaches.
  - Provide insight into, and connection with, related outside activities, e.g., private industry or academia.
  - Provide insight on opportunities to provide public outreach and educational materials.
  - Provide guidelines and recommendations consistent with the Project goals and objectives.
  - Provide recommendations for topics to consider in NRAs

The SHFE STWG is chartered by NASA Headquarters to review and provide guidance and recommendations in all areas of concern to the SHFE Program. Members are selected by the NASA Headquarters AHST Program Lead, based upon recommendations by NASA JSC AHST Program Manager and the SHFE Project Manager. The SHFE STWG will consist of four to eight members having a nominal term of 3 years, staggered to provide continuity and renewable at the discretion of the AHST Program Lead after coordination with the AHST Program Manager and the SHFE Program Manager. The Chair of the SHFE STWG will be appointed by the NASA Headquarters AHST Program Lead after coordination with the NASA JSC AHST Program Manager and the SHFE Program Manager. Generally, the chair will be selected from the active membership of the SHFE STWG and will have a nominal term of 1 year, renewable at the discretion of the AHST Program Lead.

SHFE STWG members will be chosen with the goal of attaining a balanced representation of experience, including government, industry, and academia, and should have recognized expertise in appropriate scientific and technical areas. The SHFE STWG should include SHFE Project customers such as crewmembers, who best comprehend the ultimate use of our efforts; individuals having some cross-cutting interaction with the Advanced Environmental Monitoring and Control Project and/or the

Advanced Life Support Project in the AHST Program; as well as other members outside the SHFE Project who can lend perspective from industry or academia. The SHFE Project Manager will appoint an Executive Secretary from the SHFE Project office. The Executive Secretary will work with the STWG Chair on administrative issues, e.g., meeting planning and membership issues.

#### 5.2.6 Field Center Responsibilities

The JSC is the lead center for the SHFE Project. JSC will provide the technical lead and Project Management for SHFE. Discussions with other NASA Field Centers may in the future lead to accountable roles for these centers to play in the Project.

### 5.3 Processes

#### 5.3.1 NASA Research Announcements (NRAs)

The NRA solicitation and selection processes are conducted by the Bioastronautics Research Division at NASA Headquarters, with SHFE Project participation and support. The contracting officer's technical representative (COTR) for all SHFE grants awarded under the annual NRA process is assigned at JSC. Additional matrixed assistance in administration is gained as required. The Space Human Factors: Critical Research and Technology Definition document (October, 1996) serves as a tool for identifying and prioritizing specific topics for solicitation and selection. In addition, JSC will use the Critical Path Roadmap (CPR) as another tool to guide the SHFE Project's recommendations to NASA Headquarters regarding relevance and feasibility.

#### 5.3.2 Technology Development Projects

The SHFE Project's selection of technology development projects will follow a process analogous to the NRA approach, but more expeditious and less formal. Where NRA grants are intended for basic research, these projects are intended for mid-level technology developments, pilot studies, ground tests, and in-flight technology demonstrations required before operational systems are produced and implemented.

The SHFE Project will determine needs by identifying high priority technology gaps, based on the CPR. The STWG will then review the gaps and priorities, and potentially recommend adjustments. Based on these needs, the SHFE Project requests responsive project proposals for specific needs (i.e., not general solicitations) from supporting NASA centers and/or extramural organizations. At a minimum, project proposals will include a description of the task and methodologies to be used, a schedule for products and deliverables, the required funding profile, and some evidence of ability to succeed.

After an initial review by SHFE Project management, the STWG performs an external review of project proposals for scientific and technical merit. Of those that pass the STWG review, the SHFE Project Manager recommends a prioritized list of projects to fund. NASA Headquarters' Bioastronautics Research Division (BRD) provides final

approval. The STWG periodically reviews the progress of certain projects and recommends whether they should be continued. This process is depicted in Figure 3.

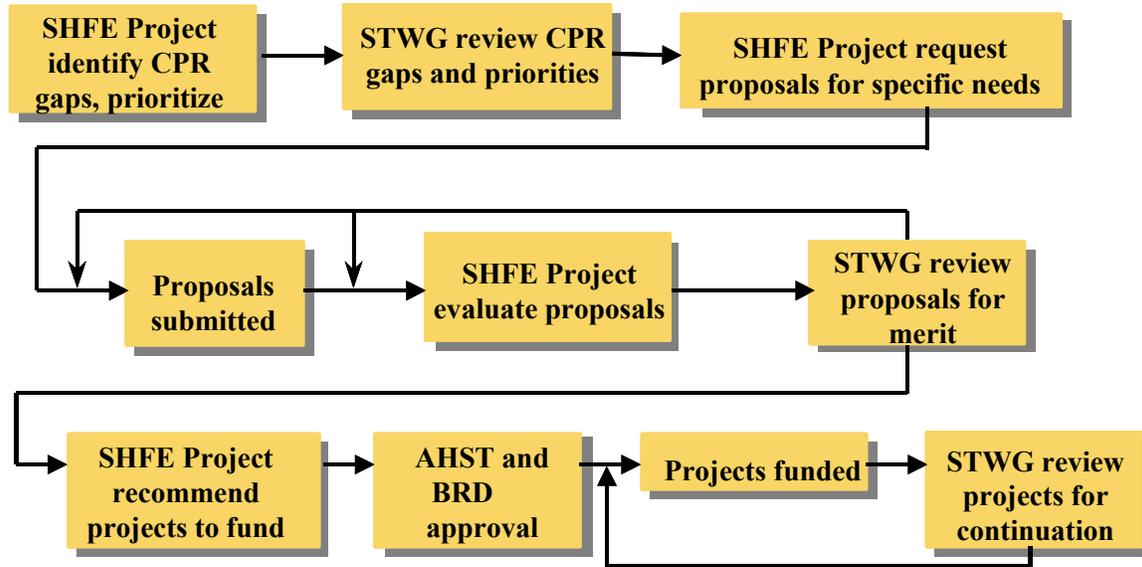


Figure 3. Process for selecting technology development projects.

## **6.0 TECHNICAL SUMMARY**

The SHFE Project is responsible for outlining the critical research needed, and developing and testing enabling technologies, for long-term exploration and habitation of space. Advances in technologies such as adaptive human-machine interfaces and information management are crucial for long duration space flight. The iterative validation approach used in previous NASA programs, where slated crew members practice all planned and contingency tasks on high-fidelity simulators, will not fully meet the needs of long duration missions. Likewise, the distributed mission control function (where hundreds of experts continuously monitor real-time systems health and plan responsive and preventive actions) needs to be replaced by methods and systems requiring far less human involvement. In order to support mission design, planning, readiness verification, and execution, the SHFE Project must develop new simulation, modeling, and analysis tools and strategies to quantify human performance capabilities and limitations in the long duration space mission environment.

The SHFE team will draw on experience, hardware, and data generated during past missions and ground-based research to form the basis for the technologies to be developed and evaluated as components of the AHST Program. Ground-based analogs will be used to develop measures and validate concepts, and ISS flight opportunities will be used to verify expected ranges of human-machine performance and to obtain

meaningful subjective feedback on proposed systems. This will allow the appropriate definition of design requirements for all human interfaces on exploration missions. It is essential to bring the human factors research community together to identify synergies and overlaps within the discipline. It is also important to identify mutual interests between the human factors discipline and other disciplines within NASA, such as behavior and performance, automation and robotics, and mission operations (see Figure 4). Part of the SHFE Project's strategy will be to use the multi-disciplinary resources currently available across the Agency, and to focus the research community so that the work done is maximally useful to the needs of the AHST Program.

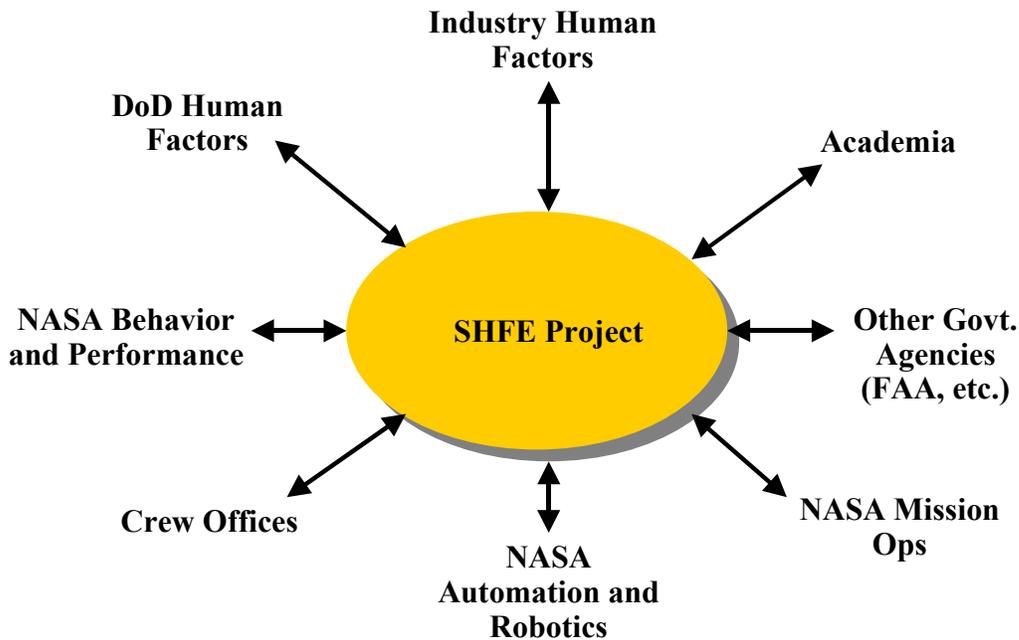


Figure 4. Interactions with the SHFE Project necessary for maximal benefits.

### 6.1 Basic and Applied Research

The SHFE Project sponsors intramural research carried out at NASA field centers and extramural research carried out by investigators at universities and other research establishments worldwide. Specific emphases will change from year to year, but generally research sponsored by the Project will focus on the following:

- Identifying and defining functions that are critical to crew productivity and well being
- Developing and applying realistic human-machine scenarios for use in overall system assessments

- Determining long-term individual and group performance responses to space (physical, cognitive, perceptual, psychosocial and cross-cultural)
- Identifying critical factors affecting those responses and understanding underlying mechanisms involved in behavior and performance
- Determining human habitability requirements for space flight
- Developing and validating the design and performance requirements for equipment and procedures, operations, and environments in space and ground support from the human factors viewpoint
- Developing and using ground-based models and analogs for studying space-related human performance
- Identifying and evaluating space human factors technologies that have applications beyond the space program

The SHFE Project will consider research proposals that are solicited through a NASA Research Announcement or Announcement of Opportunity or unsolicited. All proposals must be consistent with Project goals (section 2.0).

## 6.2 Technology Development Projects

Technology development projects should concentrate on producing new designs and mid-level technologies, performing pilot studies, and demonstrating systems for space- and ground-based operations. The Critical Path Roadmap (CPR) risks and critical questions drive the solicitation, selection, and prioritization of the technology development projects. (Relevant content in the CPR, and elaboration to a lower level of detail, are included in the annual SHFE Project implementation plans.) Therefore, the specific needs will change from year to year as priorities evolve. Examples of important mid-level technologies include the following:

- Advanced displays and controls development: The goal is to improve display and control techniques, both computer-driven simulators (the "glass cockpit") and analogs. The emphasis will be on developing new capabilities to enhance performance and safety.
- Human-machine function allocation: The increasing complexity of automation in human-machine systems raises many human factors issues. Cognitive analysis of new systems is necessary to ensure that human and machine are able to function knowledgeably and cooperatively and that task allocation is appropriate. Also needed are requirements and guidelines for designing interfaces and modes of human-machine interaction and training approaches and procedures to guide the use of such systems.

- Interaction among intelligent agents: Human interactions, with other humans and with intelligent machines, become increasingly important as missions become more diverse and longer in duration. Current knowledge in this area of human-factors analysis is very limited. Research is needed to understand the complexity of relationships among intelligent agents, focusing on psychosocial factors, group dynamics, multicultural issues, information transfer, and determinants of performance effectiveness in such teams. Knowledge gained from this research must then be applied to the design and development of spacecraft, flight procedures, habitability, ground operations, payload processing, maintenance, and training.
- Biomechanical modeling, anthropometric and kinematic methodologies, psychophysics, physical and mental work capacity measurements, and unit and team task analysis can help to establish guidelines for tool design, workplace layout, human-machine interfaces, work protocol, posture maintenance, body control, and material handling limits for intravehicular and extravehicular activity. Major concerns include sensory/perceptual and cognitive issues and human strength, stamina, range of motion, workload, and fatigue.
- Analog studies: Earth-based testing and training facilities are critical to the design, development, and maintenance of space human-machine and habitability systems. Research in high-fidelity mockups and training simulators is necessary, as well as in general environmental analogs for space missions (including acoustics, limited volume, isolation, etc.). Analog studies should address enhancing human performance in operational procedures for both in-flight and ground-support personnel.
- Information management, such as communication, recognition, and mission autonomy challenges.

## **7.0 SCHEDULES**

Schedules for deliverables and milestones are driven by technology priorities, and by resources available. The annual SHFE Project implementation plans provide details on schedules for deliverables and performance milestones in support of the SHFE Project goals and objectives.

## **8.0 RESOURCES**

Resource requirements for the SHFE Project are developed, reviewed, and updated annually according to Agency and OBPR Program Operating Plan guidance and

direction. The resource appropriations to this project are described within the details of the annual operating plans.

## **9.0 CONTROLS**

### 9.1 Management Controls

Project-level controls will be accomplished by means of periodic technical cost and status reviews. These reviews will occur quarterly at a minimum, and shall be at the discretion of the SHFE Project Manager at other times.

Schedules will be maintained for each funded activity within the Project. Significant variances in schedule will be explained, and a mitigation plan will be presented, by the respective principle investigator.

Changes to this SHFE Project Plan are approved by the SHFE Project Manager and the AHST Program Manager.

### 9.2 Flight Resource Controls

The JSC Space and Life Sciences Directorate Flight Activities Control Board (FACB) is the management control for all SHFE and AHST flight products.

## **10.0 IMPLEMENTATION APPROACH**

The annual SHFE Project implementation plan details the major activities to achieve project goals and associated metrics. A majority of the project funding is dedicated to peer reviewed research grants through the NRA process administered by NASA Headquarters. A growing portion of funding supports the technology development projects. In addition to these two primary activity paths, a smaller portion of the SHFE project resources supports the following:

- Provide core capabilities funding for the Space Human Factors Laboratory within the Space Human Factors Branch of the Flight Projects Division at JSC. Maintenance of state-of-the-art facilities for conducting space human factors analyses and evaluations is the object of this set-aside.
- Sponsor the Department of Defense Human Factors Technical Advisory Group, and provide a representative to the biannual conference where advances within the human factors discipline are shared between the agencies.

- Support the logistics of holding an annual workshop where the Project's Principle Investigators can come together and share their progress with the Project Manager and support staff.

Additionally, the SHFE Project Manager has traditionally held a seat as the NASA representative on the Human Systems Information Analysis Center Steering Committee, a group charged with administering the Department of Defense human factors data gathering, analysis, archiving, and distribution activities.

### **11.0 ACQUISITION SUMMARY**

The following elements summarize the acquisition strategy for the SHFE Project:

- Ensure adequate review of major acquisitions, such as the process previously discussed for technology development projects.
- Fully utilize performance-based contracts relative to in-house contractors that provide clear and concise performance metrics.
- Utilize the established grant process for peer-reviewed research solicited via NASA Research Announcements.
- Utilize Small Business Innovative Research (SBIR) proposals in a manner consistent with Project and Agency goals and objectives.

### **12.0 PROGRAM/PROJECT DEPENDENCIES**

N/A

### **13.0 AGREEMENTS**

Applicable agreements include:

- Program Commitment Agreement, Advanced Human Support Technology Program

- Memorandum of Understanding between Johnson Space Center and Ames Research Center Regarding Common Interests in the Astrobiology and Bioastronautics Programs

#### **14.0 PERFORMANCE ASSURANCE**

Performance goals and metrics will be addressed in the annual implementation plans.

#### **15.0 RISK MANAGEMENT**

Formal risk management plans will be developed for all SHFE Project flight experiments and systems. The risk management program will consist of the following steps:

- Risk identification
- Risk analysis
- Risk abatement
- Risk management

#### **16.0 ENVIRONMENTAL IMPACT**

N/A

#### **17.0 SAFETY**

The SHFE Project shall adhere to all applicable Agency safety requirements, procedures, and policies. Flight projects will include formal safety programs according to the applicable flight program's requirements.

#### **18.0 TECHNOLOGY ASSESSMENT**

The SHFE Project will serve as the pathfinder for development and testing of advanced human factors science and technologies with potential uses in space. Technology development focuses on "Technology Readiness Levels" 1 through 6 as defined in Figure 5. Science development focuses on "Science Readiness Levels" 1 through 6 as defined in Figure 6. Technology assessments and testing will proceed according to established methodologies including periodic design reviews, testing, inspections, and data collection, analysis, and distribution.

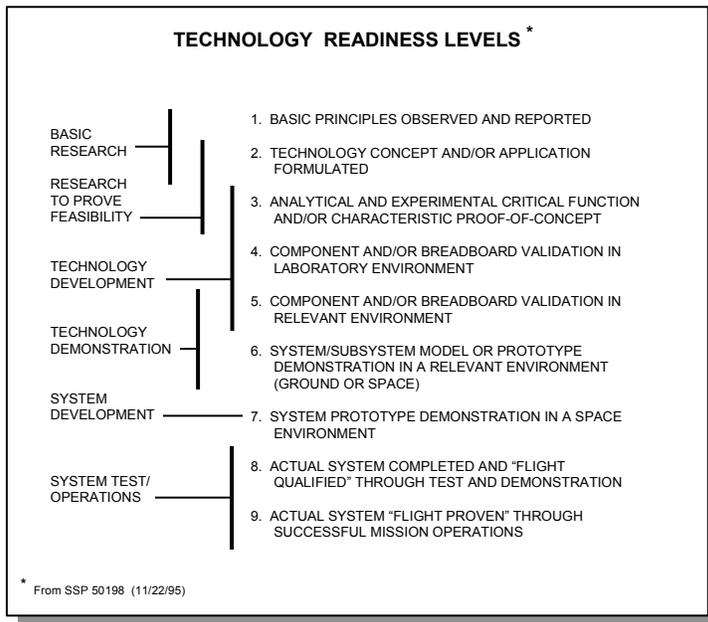


Figure 5. Technology Readiness Levels

<b>Science Readiness Levels</b>	
1	Advanced studies
2	Develop, evaluate feasibility of approach, establish and test initial hypotheses
3	Develop and test models
4	Defined in sufficient detail to establish baseline
5	Provides complete detailed design of system
6	Development and integration of system for testing operational readiness in relevant environment
7	Development of system prototype in space
8	System flight qualified through testing and demonstration
9	Implemented and operational readiness proven

Figure 6. Science Readiness Levels

## **19.0 COMMERCIALIZATION**

The SHFE Project will foster commercialization opportunities to establish partnerships to transfer technologies, discoveries, and processes with potential for commercialization. Plans may be developed for program specific technology, multi-use technology, or new crosscutting technology.

## **20.0 REVIEWS**

An annual review of the SHFE Project will be conducted for the Project Manager and the AHST Program Manager. This may be accomplished as a separate SHFE review, or in conjunction with larger Bioastronautics reviews and workshops. Special reviews will be conducted as needed.

## **21.0 TAILORING**

N/A

## **22.0 CHANGE LOG**

Changes to this Project Plan will be documented in the change log attached at the end of this document.

**DOCUMENT CHANGE LOG FOR**

**JSC29022**

REVISION LETTER/DATE	AUTHORITY FOR CHANGE	PAGES AFFECTED	BRIEF DESCRIPTION OF CHANGE	AFFECTIVITY END ITEMS/ SERIAL NO.
Rev. A, October 2001	T. Rathjen	all	Reflect changes in line organization; update information on advisory panels.	